Performance Evaluation of Routing Schemes in Wireless Sensor Networks for Train Monitoring

Oussama Drissi[1], Adel Omar Dahmane[1] and Tayeb Medjeldi[2]

[1]*Microsystems and Telecommunications Laboratory, Universite du Quebec a Trois-Rivieres, Trois-Rivieres, QC, Canada*

[2]*College Center for the transfer of telecommunication technology, Trois-Rivieres, QC, Canada*

Keywords: Routing Scheme, Wireless Sensor Network (WSN), Mesh Network, WI-FI, Power Consumption, Multi-tier Architecture, Multi Hop, Shadowing.

Abstract: Wireless sensor technologies offer new opportunities in different applications thanks to the great technological progress in the development of smart sensors, powerful processors and wireless communication protocols. In this paper, performance evaluation of two network topologies based on routing strategies for train monitoring has been conducted in a realistic mesh sensing system. Results conducted in NS2 using Mannasim extension show that Multi-tier multi-hop topology outperforms the classic multi-hop topology in terms of end-to-end delay, throughput and residual energy level.

1 INTRODUCTION

Today, wireless sensor networks attract interest in both industrial and research community network. The technical developments in micro-electro-mechanical systems (MEMS) and wireless communications allow the realization of wireless sensor networks with a large number of sensor nodes at low cost (Kiziroglou et al., 2011). The wireless sensor networks are composed of nodes with limited power and processing. They can be deployed quickly in sensitive and inaccessible areas. Their mission is most often to monitor an area, take regular measurements and to trace alarms to certain nodes of the network called sink, capable of relaying information on a large scale (Akyildiz et al., 2007). Many WSN applications are emerging in areas as diverse as defense, security, health, agriculture, smart homes, and transportations. For example, the rail network needs to improve services to its trains to satisfy the customer expectations and to deal with the increased demand for railway services. Therefore, WSN is a good choice to ensure a reliable, secure and comfortable service by sensing a set of parameters in each wagon such as temperature, acceleration and humidity (Viani et al., 2010).

WSN can be deployed with a star topology where PAN coordinators are needed; or with a mesh network where the network is self-formed and self-healed. Although many applications involve WSN, they have to overcome several constraints (Wang et al., 2011) including end-to-end delay, throughput, power consumption and number of hops. The latter becomes a serious threat to the deployment of WSN in trains. In (Mahasukhon et al., 2010), authors have proposed a new protocol scheme based on muti-tier. They have reduced the number of hops by dividing the train wagons into several small multi-hop segments based on ZigBee. These segments were connected through Wi-Fi. However, in their study, they have considered only one sensor per wagon. Moreover, the WSN chosen is based on ZigBee with the star topology where a PAN coordinator is mandatory. The use of PAN coordinator is not recommended for energy constrained applications. In this case, mesh networks are preferred. In this paper, we consider data transmission from sensor nodes placed in wagons to the sink located in the train headboard via mesh network. We propose to use chain-topology multi-hop wireless sensor networks. This work implements this approach using AODV routing protocol in a realistic shadowed environment. The performance study will focus on reducing the number of hops to the sink and compare results between the routing schemes aboard a train using NS2 and Mannasim extension.

The remainder of this paper is structured as follows: In Section 2, we introduce the main WSN

Drissi O., Omar Dahmane A. and Medjeldi T..
Performance Evaluation of Routing Schemes in Wireless Sensor Networks for Train Monitoring.
DOI: 10.5220/0004697200820086
In *Proceedings of the 3rd International Conference on Sensor Networks* (SENSORNETS-2014), pages 82-86
ISBN: 978-989-758-001-7

routing schemes that are considered in this paper. The simulation environment and setup are presented in section 3. Then, in Section 4, performance metrics and comparison results are presented. Finally, conclusions are drawn in section 5.

2 SYSTEM MODEL

2.1 Network Topology

The design of protocols for routing information of a WSN is closely related to the network topology considered. In this paper, two network topologies are presented in order to study the impact of reducing the number of hops in the overall performance of the network for train monitoring.

2.1.1 Classic Multi-Hop Network Topology

Our model consists on 37 nodes distributed as illustrated in Figure 1 on a square area of 100 x 100 m². We consider a train that contains 9 wagons and a headboard that contains the sink node. Each wagon contains 4 sensor nodes. The nodes sense, continuously, a chosen parameter. Then, it sends data to the sink via multi-hop. Consequently, the network has 36 similar nodes and we consider that the sink node has ten times more energy level than simple nodes. The mesh network formed by the 37 nodes is based on the IEEE 802.15.4 standard (IEEE SA Standards Board, 2003) for the physical and MAC (Medium Access Control) layers to ensure low cost and low energy consumption.

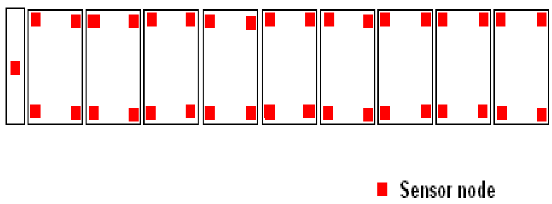

Figure 1: Classic multi hop network topology.

2.1.2 Multi-Tier Multi-Hop Network Topology

In this section, we adopt the Wi-Fi to form an upper layer multi hop network. Thus, we add 3 access points to the previous topology as shown below. We consider that these access points are powered by the train on the same square area of 100 x 100 m². In real deployment of such scheme, existing Wi-Fi access points in modern trains can be used. The total number of nodes is then 40 nodes.

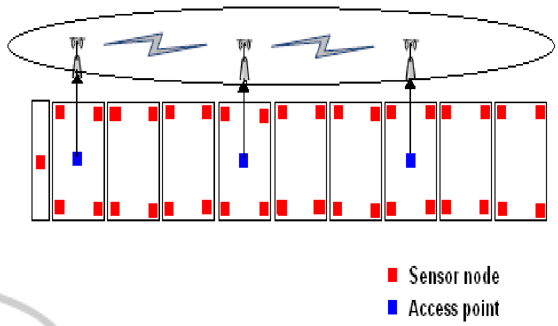

Figure 2: Classic multi hop network topology.

2.2 Routing Protocol

Routing protocols in WSN are influenced by energy consumption constraint. The sensors use their energy for the purpose of data processing and transmission. The lifetime of a sensor depends mainly on its battery. Sensor node failure can change significantly the network topology and can impose a costly reorganization of the latter. In this work, AODV (Ad hoc On Demand Distance Vector) routing protocol is considered. AODV is a distance vector protocol (Shuangyin et al., 2012). It uses sequence numbers to avoid routing loops and to indicate the new paths to the destination node.

An entry in the routing table contains essentially the address of the destination, the address of the next node, the distance in number of hops and the destination sequence number. AODV path discovery process begins when a node send a RREQ packet (Route request message), which is relayed by intermediate nodes until the destination responds with a RREP (Route reply). The routing tables of nodes are updated after each retransmission of the RREQ and RREP messages.

Although AODV is considered in this paper, other routing protocols can be evaluated using the same network model.

3 SIMULATION SETUP

To evaluate the performance of the two network topologies, we have used NS2 along with Mannassim extension.

Mannassim allows extending the functions of NS2 by adding new modules to the design, development and analysis of various WSN applications such as detection of temperature change, battery model and radio propagation model (The Manna Research Group, 2006). Table 1 summarizes the simulation parameters.

Table 1: Global simulation Parameters.

Parameter	Value
Channel type	Channel/Wireless channel
Radio-propagation model	Shadowing visibility
Network interface type	Phy/WirelessPhy
MAC type	Mac/802.11, 802.15.4
Antenna	Antenna/Omni Antenna
Energy model	EnergyModel/Battery
Interface queue Type	Queue/Drop Tail
Initial energy level (J)	10
Area (m*m)	100*100

3.1 Radio Propagation Model

A new radio propagation model called shadowing visibility is provided by Mannassin that changes the shadowing parameters depending on the visibility between sensor nodes. If both nodes are in line of sight, this model uses a good propagation paradigm.

Otherwise, it changes the shadowing parameters to ensure bad propagation paradigm (Rhattoy et al., 2012). Thus, shadowing visibility switches between two paradigms depending on the visibility between sensor nodes which allows a more accurate simulation model to represent a realistic environment as illustrated in table 2.

3.2 Node Configuration

A sensor node ensures temperature change sensing, processing task and data generation. The creation of an application layer using Mannasim, that detects the change in temperature and generates data to the sink, allows accurate results at the expense of a more complex node configuration. Table 3 shows all node's parameters that are possible to configure using Mica 2 mote setup.

Table 2: Radio propagation model parameters.

Shadowing paradigm	Parameter	Value
Good propagation conditions	Path loss exponent	2.0
	Deviation (dB)	3.0
	Close-in reference distance	30.0
Bad propagation conditions	Path loss exponent	3.0
	Deviation (dB)	5.0
	Close-in reference distance	1.0

Table 3: Full node configuration.

Parameter	Value
Sensing type	Continuous/On demand
Disseminating interval (s)	2.0
Reception power (J)	0.024
Transmission power (J)	0.036
Sensing power (J)	0.015
Processing power (J)	0.024

4 RESULTS

To evaluate the performance of network topologies, we have used AODV routing protocol in a realistic environment by exploiting shadowing visibility radio propagation model.

We assume that all nodes have a fixed position during the period of simulation using the parameters mentioned in the previous tables. The performance comparison between the two topologies is based on the following metrics:

- **End-to-end delay:** is the time spent by a packet to travel across the network from source to destination

- **Throughput:** is the average rate of successful message delivery over a communication channel. These data may be delivered over a physical or logical link, or pass through a certain network node.
- **The Residual Energy**: is the level of the residual energy of nodes relative to the initial energy during the simulation.

4.1 End-to-end Delay

Figure 3 reports the end-to-end delay of traffic generated by sensing temperature changes at nodes obtained by both topologies. The sensing type is continuous and the aggregated data is then sent to the sink at a regular interval of 2 s.

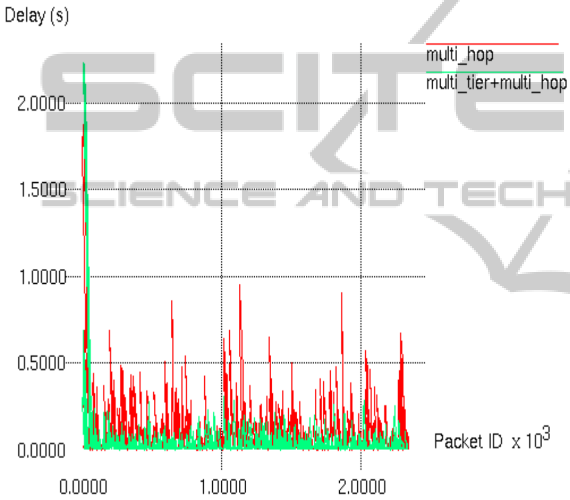

Figure 3: End-to-end Delay.

The end-to-end delay of the classic multi hop approach reached 1.9 s during the period of path research in a shadowed environment compared to about 2.4 s for the multi-tier multi-hop topology.

This result was expected since the latter comes with the expenses of an extra setup time due to the upper layer. However, as shown in figure 3, this approach outperforms the classic multi hop scheme on the end-to-end average delay once the network reaches the state of convergence.

4.2 Throughput

Figure 4 shows the network throughput for each topology. We notice that the instant network throughput of multi-tier multi-hop routing scheme in shadowed environment is about 5 Kbits while the classic multi-hop routing scheme gives a lower instant throughput.

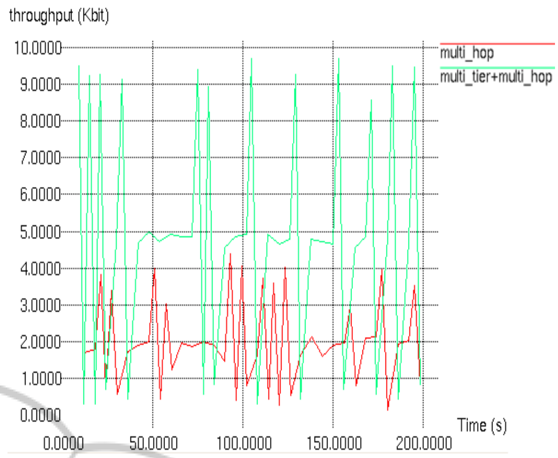

Figure 4: Network throughput.

4.3 Residual Energy Level

All nodes in the network simulation start by initial energy level equal to 10 (J). Each node in the network will consume energy to ensure sensing task, data processing and communication with other sensor nodes. To compute the energy expended for each sent or received data, we used the model of radio power dissipation proposed in table 3. Figure 5 shows the residual energy of sensor node for each simulation scenario.

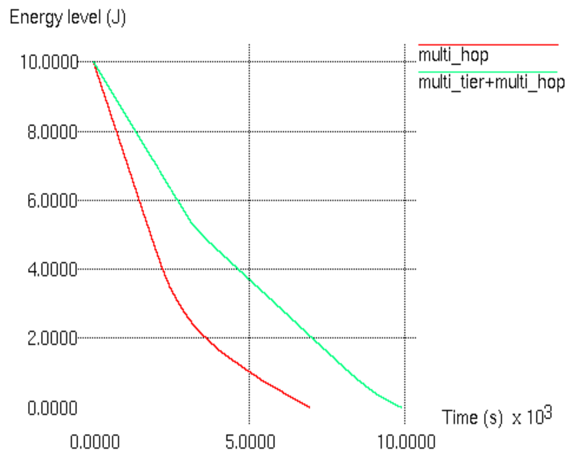

Figure 5: Residual energy of sensor node.

In a shadowed environment, the use of Wi-Fi network to reduce the number of hops along the train from the source node to the sink was efficient in term of power conservation. Consequently, a sensor node will be alive for a longer time compared to the classic multi hop routing scheme.

4.4 Summary of the Comparison between Routing Schemes

The proposed multi-tier multi-hop routing scheme provides better performances in terms of average throughput and end-to-end average delay in realistic environment as summarized in table 4. Moreover, this approach extends the network lifetime to ensure sensing tasks for a longer duration as shown in Figure 6. Indeed, simulation results show that the multi-tier multi-hop routing scheme keeps 50 % of sensor nodes alive for duration three times more than the classic multi hop scheme.

Table 4: Comparison between routing schemes.

	Average Throughput [kbps]	End-to-end average delay (ms)
Multi-tier multi-hop routing scheme	5.06	29.03
Classic multi-hop routing scheme	3.11	312.80

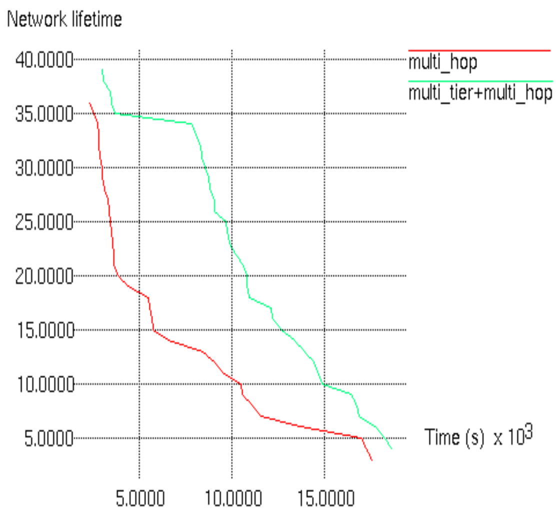

Figure 6: Network lifetime.

5 CONCLUSIONS

In this paper, performance evaluation of routing schemes using AODV routing protocol in a realistic environment for train monitoring has been conducted. Multi-tier multi-hop routing scheme, by reducing the number of hops, has been shown better performance in terms of end-to-end delay, throughput and the residual energy of sensor node.

The use of Wi-Fi to divide the train into three parts has allowed reaching a network lifetime three times longer than the classic multi-hop scheme. In future work, AODV and other routing protocol techniques will be investigated when mobile nodes are present in the mesh network.

REFERENCES

Kiziroglou, H. C., Michail, E., Yates, D. C., Yeatman, E. M, 2011. *A MEMS Self-Powered Sensor and RF Transmission Platform for WSN Nodes, Sensors Journal*. IEEE.

Akyildiz, I., Su, W., Sankarasubramaniam, Y., and Chowdury, K. R., 2007. Wireless multimedia sensor networks: A survey. *Wireless Communications. IEEE.*

Viani, F., Oliveri, G., Donelli, M., Lizzi, L., 2010. WSN-based solutions for security and surveillance, *Wireless Technology Conference (EuWIT)*. IEEE.

Wang, Y., Li, X.Y., Song, W.Z, Huang, M., and Dahlberg, T. A., 2011. Energyefficient localized routing in random multihop wireless networks, Parallel and Distributed Systems, *IEEE Transactions on. IEEE.*

Mahasukhon, P., Sharif, H., Hempel, M., Zhou, T., 2010. Multi-tier Multi-hop Routing in Large-scale Wireless Sensor Networks for Real-time Monitoring, *Sensors, IEEE.*

IEEE SA Standards Board, 2003. IEEE 802.15.4, Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate WirelessPersonal Area Networks (LR WPANs), IEEE.

Shuangyin, R., Huanmin, H., Baoliang, L., Jia, L., Cgao P., Wenhua D., 2012. An Improved Wireless Sensor Networks Routing Protocol Based on AODV, Computer and Information Technology (CIT), 2012 IEEE *12th International Conference on. IEEE.*

The Manna Research Group, 2006. Mannasim Framework Classes Manual, Sensornet project. Mannasim.

Rhattoy, A., Zatni, A., 2012. The Impact of Radio Propagation Models on Ad Hoc Networks Performances, *Journal of Computer Science.* Science Publications.